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AUTHOR	Hansen, Duncan N.
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ABSTRACT

Computer-Assisted Instruction (CAI) is surveyed in terms of both the extent of research progress as well as the degree of utilization for this new technological approach to education. After a brief review of some of the critical terminology used to describe research progress within CAI, a conceptual framework by which to consider current investigatory efforts is developed. The psychological nature of the CAI situation, concepts of how CAI provides for individualization of instruction, and the procedures and research findings for the use of instructional strategies are examined in detail in the major part of the paper. A discussion of learner strategies and their growing importance within CAI in learning investigations concludes the paper. (Author/SP)

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CAI CENTER

TECH MEMO

CURRENT RESEARCH DEVELOPMENT IN COMPUTER-ASSISTED INSTRUCTION

Duncan N. Hansen

Tech Memo No. 17
February 15, 1970

Project NR 154-280
Sponsored by
Personnel & Training Research Programs
Psychological Sciences Division
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FLORIDA STATE UNIVERSITY

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Computer-Assisted Instruction (CAI) is surveyed in terms of both the extent of research progress as well as the degree of utilization for this new technological approach to education. After a brief review of some of the critical terminology used to describe research progress within CAI, the paper develops a conceptual framework by which to consider current investigatory efforts. The first section deals with the psychological nature of the CAI situation. The second, introduces concepts of how CAI provides for individualization of instruction. Third, it introduces the procedures and research findings for the use of instructional strategies. The paper concludes with a discussion of learner strategies and their growing importance within CAI in learning investigations.

CURRENT RESEARCH DEVELOPMENT IN COMPUTER-ASSISTED INSTRUCTION[1]

Introduction

Computer-assisted instruction (CAI) is now more than a decade old. Having moved from a conceptual idea, CAI is starting to prove its operational feasibility in the United States. Moreover, CAI has started to document an impressive array of increased instructional effectiveness for such curricular areas as elementary school mathematics, reading, junior high science, college physical science, computer science, and teacher training. In the United States, it is estimated that in excess of 50 percent of the colleges and universities are actively exploring the utilization of CAI. On the other hand, it is estimated that less than 10 percent of our public schools has some active research project in the CAI area. Given the short period with which computers have been utilized for this type of instruction, these developmental statistics indicate the speed with which computer technology is spreading, at least in the United States. As a major thesis of this paper, it will be contended that the conceptual framework for CAI development has not progressed rapidly beyond the initial conjectures made during the late 1950's.

As is true for any new developing field, the initial conceptualizations about CAI were formulated at a simplistic or relatively crude level. The use of computers for instruction have tended to become known by the nature of their application. When CAI is considered,

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the following kinds of applications have tended to evolve: (1) drill and practice that provides a potential automation of the problem-solving routines or homework to be mastered by a student; (2) tutorial approaches that attempt to replace the teacher in as complete a manner as possible; (3) problem-solving tasks that use the computer both as a problem-structuring device and as a calculational tool for generating answers; (4) simulation problems that attempt to replace many of the empirical activities such as found in our science laboratory with symbolic representations provided by the logical and stochastic capabilities of computers; and (5) evaluation tasks via computer that result both in sequential testing and more sophisticated forms of data analysis. In essence, these applications represent a match between the computer as a tool and a specific educational problem.

This paper will attempt to illustrate that it is possible to develop a conceptual framework by which to consider the significant research problems within CAI. The substance of this paper will be divided in four sections: (1) the psychological nature of CAI, (2) individualization of instruction, (3) the concept of instructional strategies, and (4) the concept of learner strategies. These topics have been selected because they are most commonly discussed and studied by investigators in the CAI world. The presentation will focus on both ambiguities as well as conceptions for formulating reasonable propositions worthy of investigation. By focusing on the topics of the nature of CAI, individualization, instructional strategies, and learning strategies, it is hoped that CAI research in the future will become more coherent in nature.

Nature of Computer-Assisted Instruction

CAI can be defined as a form of human machine interaction whose goal is the efficient learning of the desired curriculum. In terms of the computing system, the pedagogical alternatives open to the CAI designer are as follows: (1) selection of an appropriate media device for presentation of the curriculum; (2) control of the rate of presentation; (3) control of the sequence of items within the curriculum; (4) concurrent recording of all learning behaviors, and most importantly; (5) a decision mechanism by which the rate and sequence of curriculum elements are presented to the student. This decision mechanism is commonly referred to as an instructional strategy although the consideration of the selection of media is also commonly included under this rubric. Optimization refers to the increase in efficiency found for one instructional strategy as opposed to another instructional strategy.

Before proceeding, it may be useful to characterize the instructional paradigm for CAI more explicitly. First, the curriculum to be taught can be conceptualized as a set of presentation elements, P_i, which includes both presentation information as well as a question. For each of these P_i elements there should exist one or more correct responses, R_i. These P-R pairs may be as simple as the pronunciation of the word "fun" with the requirement to spell it, or as complex as answering the question "How did the astronauts reach the moon?" after reading a thousand word passage on the topic. Referring to Figure 1, an instructional session is started by initializing the prior learning history for a given student and determining which curriculum element

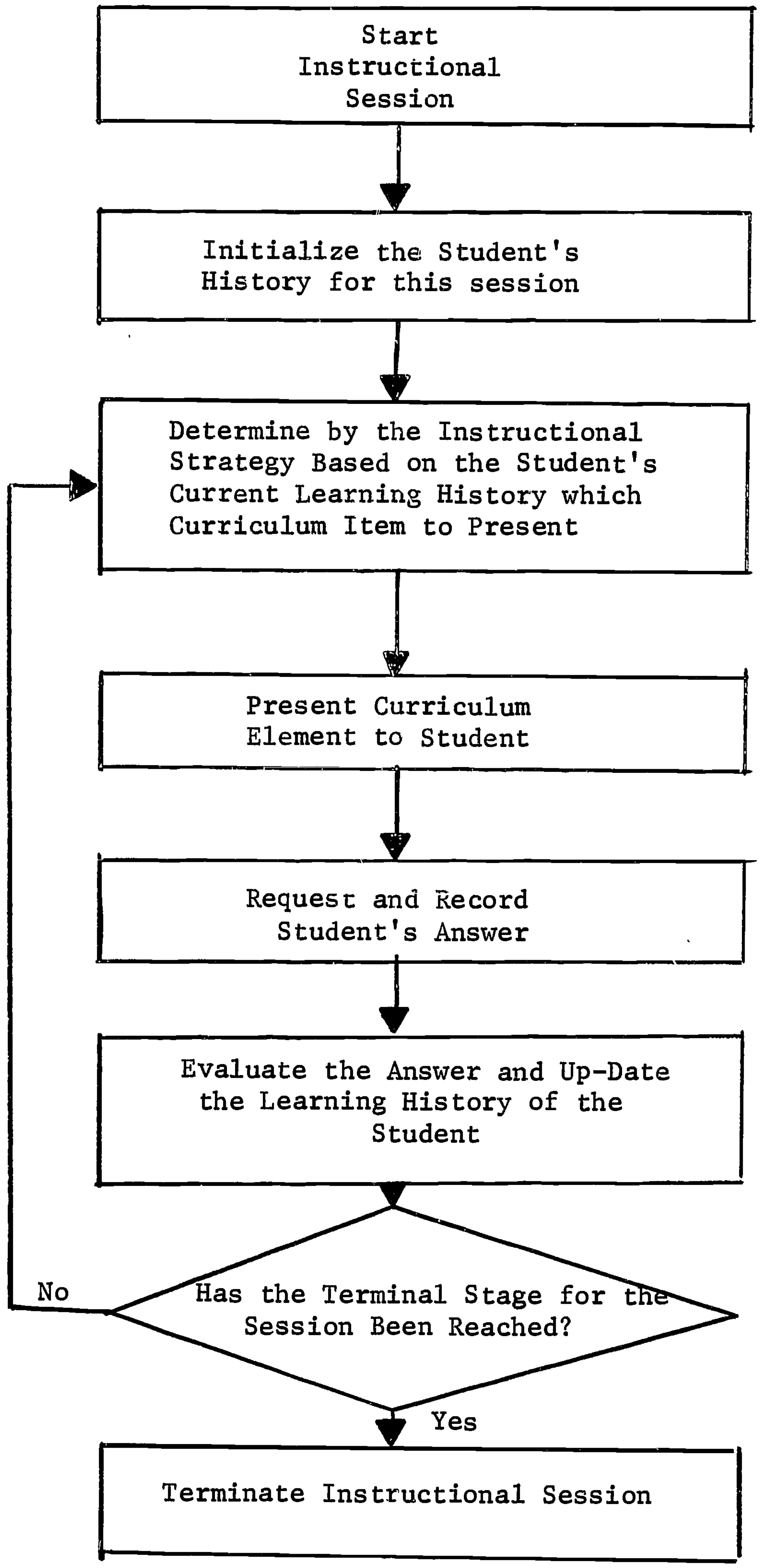

Fig. 1.--The instructional paradigm for CAI

to present to him. Once the curriculum element has been presented to the student, a response is requested and recorded within the CAI system. This response can be evaluated via a pre-stored set of answers and symbolic matching techniques. This in turn allows the system to update the learning history of the student. If the terminal element in the curriculum has not been reached, the system then branches back to the instructional strategy which determines the next curriculum element to be presented. If the instructional strategy bases its selection contingent on the previous learning history, the system can be referred to as dynamic (response sensitive in Groen and Atkinson's terms, 1966). On the other hand, if the selection is independent of the learning history of the student, then it can be characterized as static. The distinction between dynamic and static instructional strategies is highly important, in that optimal solutions can be derived for either, but the best evidence to date indicates that dynamic instructional strategies ultimately will provide for the individualization hoped for by CAI.

In terms of the human learner, it is always assumed that the student has an expressed goal or purpose in mind. While alterations in the selection of curriculum elements may be based on the student's prior knowledge and aptitudes, it is commonly assumed the student strives to reach the terminal element in the curriculum sequence as fast and efficiently as possible. We have come to recognize that students develop learning strategies for both varying learning contexts as well as different instructional strategies found explicitly within CAI. These learning strategies relate to the adaptation processes of the student as to how he allocates his mental energy in regard to the encoding, storing, and consolidation of the curriculum elements. The concept of a student learning strategy is stressed in that it will be contended that optimization ultimately will be defined as an isomorphic match between the instructional strategy of the CAI system as developed by its creators with the learning strategies evolved by the students. This intuitive optimization can be quantified in terms such as reduced learning times for fixed amounts of curriculum elements, or reduced errors given that the terminal goal is based on some performance criterion level. We turn now to a consideration of individualization of instruction within CAI in order to better illuminate this match between instructional strategies and learning strategies.

Individualization

The major justification for CAI has been the individualization of the instructional process possible through this technological approach. In conceiving of individualization, most investigators have tended to define the process as one of supplying the appropriate instruction to satisfy the student's educational needs. This definition of individualization has obvious ambiguities. For example, are the educational needs to be defined from the student's frame of reference, especially in terms of his wants? Or is it to be defined by some benevolent power who prescribes what the child ought to have? The concept of needs is an internal behavioral construct within learning psychology. The problems of its definition can be witnessed within the research literature on human motivation and personality processes (Cofer and Appley, 1964).

An alternative theoretic approach would be to utilize a simplified input-output behavioral model and to assess the operational progress made via CAI within the model's conception of individualization.

Turning now to this simplified model, individualization can be thought of as a process by which the student maximizes his informational input, processing, storage, and output. In psychological terms, this conception of individualization specifies the stimulus curriculum array, the cognitive processes, and the response requirements. Breaking the behavioral processes of learning into these three components will allow us to view what research progress has been made via individualization within CAI.

In regard to stimulus input, investigators such as Briggs (1967) and Gagné (1965) assert that great learning gains can be achieved by appropriate assignment of the instructional media. Matching appropriate films, audio lectures, or printed materials to individual characteristics should, it is claimed, lead to better learning results. Currently, the Pittsburgh and the Duluth Public Schools are providing for student choices via computer scheduling among instructional media alternatives to nearly 4,000 elementary school students. Given a learning contract to achieve a certain performance objective, the student chooses among the listed available educational resources which can be books, audio records, films, etc. A similiar research project at Florida State University that involves teacher candidates indicates that: (1) there are considerable individual differences in these media choices, (2) the selection criteria seems to be based on a match between the characteristics of the objectives of the instructors and the response requirements of the learning task, and (3) media alternatives do lead to improved performance.

More specific to CAI, our own experience in three replications of an autonomous computer-based multi-media physics course at Florida State University (Hansen et al., 1969) indicated that CAI interactive problems presented over a CRT-light pen terminal lead to the greatest learning gains in comparison with the audio lectures or text reading assignments which in turn were superior to 16 mm films. Noting that the students in the CAI version of the physics course performed 20 percent better than a matched sample of students attending a conventional lecture-discussion course, Table 1 presents the mean performance on CAI questions associated with the four CAI media types and Table 2 presents the multiple regression coefficients found for each media type by lesson with the dependent measures of the mid-term and final examinations.

TABLE 1.--Mean Correct Proportions on First Responses to Different Media Presentation Types by Conceptual Topics

CONCEPTS	AUDIO	TEXTBOOK	FILMS	CAI CONCEPTION EXERCISES
Scientific Measure	.632	.698	.611	.586
Optics and Light	.670	.733	.675	.673
Force and Energy	.703	.706	.547	.666
Electricity	.675	.703	.476	.653
Modern Physics	.666	.703	.486	.605

TABLE 2.--Multiple Correlations of Media Type Categories with Examination Outcomes

	MID-TERM EXAMINATION	FINAL EXAMINATION
Audio	.733	.798
Textbook	.605	.694
Films	.587	.445
CAI Conceptual Exercises	.870	.901

It should be noted that the terminal objectives of the course stressed physics problem solving. Consequently, it is no surprise that the CAI-CRT media instruction (CAI conceptual exercises) proved superior to the other media alternatives. It is interesting though that the audio lectures were superior to films, given the large difference in information load. Using multi-media research designs, one can, in fact, separate out the various contributions of input media within CAI. As an added complexity, our last replication indicates that the individual difference factors of mathematics aptitude, state anxiety (a personality process), and attitudes toward theoretical conceptions were significant determiners of the learning outcomes and interacted with the various media utilized. Thus, the appropriate individualized assignment of media within CAI appears to be a highly complex problem.

Perhaps a more insightful example of this complexity is a recently completed study by Dick and Latta (1969) which assessed the presentation of the concepts of significant figures to two non-overlapping sampled groups of low and high mathematics ability students at the junior high level. The media contrast was that of paper and pencil programmed instruction in comparison with CAI-CRT presentation. To illustrate the learning gains, the pretest to the posttest comparison indicated a fourfold gain in performance (see Table 3).

TABLE 3.--Mean Scores on Pretest, Posttest and Retention Test for High and Low Ability Students on PI and CAI Curriculum Presentations

	LOW ABILITY		HIGH ABILITY	
	PI	CAI	PI	CAI
Pretest	7.2	7.3	8.1	7.9
Posttest	28.4	18.8	34.1	34.8
Retention Test	24.7	16.3	24 1	26.4

The major finding was the nearly identical posttest and retention means for media contrast within the high ability groups, the CAI version being slightly superior, whereas there was a significantly lowered improvement for the low ability students if presented via CAI. The large learning gains for the low ability PI group were replicated in the three-week follow-up retention test. One explanation for the low ability CAI group's decreased performance could be the heightened memory load required by CRT presentations. Thus, one can see that the assignment of appropriate media on the stimulus input side will have to be conditionalized according to at least the aptitude of a student.

In regard to internal processes, the middle component in the model, the manipulation of the level of difficulty of the learning curriculum elements has been successfully pursued, especially at Stanford University (Suppes and Morningstar, 1969). In a project presently operating in a rural county near Tallahassee, we are providing daily CAI reading instruction to an array of students spanning from primary grades up through high school. It is clear that providing for appropriate levels of difficulty within CAI reading comprehension provides for an accumulative positive outcome over a span of an instructional year. To be more specific, Table 4 presents the Fall and Spring testing results. As indicated by the IQ outcomes, these are low aptitude students. For the early grade level students, approximately one year in reading and mathematics achievement was gained while the upper grade students yielded a less substantial gain. These results are equivalent to those found in six other elementary school level CAI projects in the U. S. Clearly, adjusting the difficulty level of the CAI curriculum elements according to concurrent learning histories of the student yields positive results especially for disadvantaged or low-aptitude students.

In terms of a more specific type of individualization for mental processing, a recently completed study (Gay, 1969) indicates that sex differences in learning strategies can be important determiners. In this case, students from an eighth grade class were provided differential numbers of examples or practice on mathematics problems that represented the essential concepts of polynomials. Three conditions were contrasted: one, a fixed number of assigned exercises based on a prediction from the child's IQ score; second, an assignment based on a memory retention index; and third, student controlled or self-assignment. In this particular study, the boys under the self-assignment condition achieved superior results,

TABLE 4.--Means and Standard Deviations for Fall, 1968, and Spring, 1969, Test Results for IQ, Reading, and Arithmetic Grade Level Measures

		IQ		READING		ARITHMETIC	
	N	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
<u>GRADE 2</u>							
PRE	35	92.406	16.138	.947	.921	1.741	.647
POST	32	95.314	15.911	2.009	1.275	2.354	.740
<u>GRADE 3</u>							
PRE	44	86.727	11.679	1.993	1.350	2.555	.745
POST	44	89.318	12.400	2.921	1.607	3.248	.832
<u>GRADE 4</u>							
PRE	10	96.100	15.723	3.290	1.753	3.450	.871
POST	10	98.900	22.063	4.050	2.004	4.020	1.188
<u>GRADE 5</u>							
PRE	10	81.100	8.672	2.840	1.284	3.160	.788
POST	10	83.100	10.376	3.210	1.245	3.450	.903
<u>GRADE 6</u>							
PRE	10	79.800	10.922	4.280	1.959	3.890	.555
POST	10	79.600	9.324	4.440	1.732	4.290	.985
<u>GRADE 7</u>							
PRE	9	93.222	17.145	6.344	1.651	5.300	1.063
POST	9	97.667	20.341	6.922	2.052	5.511	.979

whereas the girls achieved superior performance levels when assigned amount of practice according to the memory retention index. While skipping over many of the details, it is clear that the measure of IQ did not provide a good predictor for the assignment of examples and practice. The important point is that the sex variable significantly differentiates the appropriate approach to utilize within individualizing the amount of practice within CAI mathematics instruction.

Turning now to the response side, the third component in the model, it seems relatively clear that very little CAI research has taken place. While we do have Rand Tablets, touch sensitive response panels, and speech analyzers available, most of the experimentation has focused on automated typewriters or CRT's with light pens. Perhaps of even more concern is the fact that all of the individualized response approaches have been symbolic in nature, i.e., these assume that the student is capable of handling some symbolic language system. As any school teacher will inform you, mastery of many concepts can be demonstrated via such responses as drawings, acting or dramatization, or constructing concrete models. Moreover, multiple responses like confidence about one's ability, trust of the situation, and concurrent anxiety can dramatically influence the CAI learning outcomes. It seems clear that a greater effort should be made on the technological side to allow for a richer array of response capabilities, and the employment for a wider variety of responses to each instructional problem.

While acknowledging that this input/output model for individualization is extremely simplified, it becomes clear that CAI research efforts have explored only a few of the individualizing alternatives that have been suggested. Moreover, our exploration of how individualization interacts with different academic curricula has received a meager start at best. The field needs a matrix of investigations by which various curricular disciplines are intersected with student populations of varying age levels. When one constructs such a matrix, one observes the preponderance of omissions or blanks. Such a simple exercise leads one to identify a compelling need for much more empirical investigation of CAI applications in varying disciplines such as art, music, English, as well as the sciences.

Speaking as a psychologist we obviously need longitudinal studies of students who are daily involved with CAI. Thus, a decade of serious empirical studies seems needed in order to build a sound research basis for our understanding of an outcome cube that represents academic curriculum, by educational levels, by CAI individualization procedures so that optimal assignments can be made for each student.

Instructional Strategy

Currently in the "CAI In-Group," one hears continuing reference to the investigation of instructional strategies. This topic was first described by Stolurow (1961) in terms of the logical flow of the instruction, that is, the branching structures utilized within the context of correcting error responses or applying remedial procedure within the flow of the curriculum elements. As a contrasting conceptual frame of reference, Smallwood (1962) proposed a quantitative model by which to define instructional strategies that lead to optimal solutions using dynamic programming techniques. As defined earlier, an instructional strategy is one that allows for a selection among the alternative rates and sequences of curriculum elements in order, hopefully, to lead to an optimal outcome. These alternatives involve the characteristics of the learner, the structure of the curriculum materials being considered, and the developmental representation of the learning processes utilized by the student in order to minimize his effort and maximize his rewards. Thus, the student from my point of view will always look to maximize his rewards and minimize his effort in terms of either playing an "interesting game" or contending with the problems posed by an educational system.

The primary issue concerns who controls the instructional strategy. At one end of the continuum, Stolurow, Smallwood, and Suppes would suggest that we prescribe the optimal selection of learning events for the student. These investigators claim that once having understood the student's basic learning processes that the educator, as an outside decision-making mechanism, can best decide this prescription for instruction. At the other end of the continuum, Grubbs (1968) has suggested that a student, given his better self-awareness of all of his internal mental processes and immediate states of awareness, can best select his own strategy for acquiring a set of complex concepts. From the framework presented in the earlier section on the nature of CAI, it is clear that Stolurow and Suppes are referring to the proposed definition of an instructional strategy, while Grubbs is referring to the proposed definition of a student's learning strategy. Each strategy is important to consider for ultimate optimization, even though each can make its own contribution. This can be documented by the beginning empirical experimentation on optimization within CAI.

Turning now to an empirical study of two learning models which considered the efficacy of dynamic instructional strategies in terms of their optimality, a group of sixty eight-year olds were presented with a spelling task via CAI. The task consisted of: (1) an auditory presentation of the targeted word, (2) an opportunity to type it, and (3) an auditory and correct orthographic presentation for student study (this is commonly referred to as the paired associate learning paradigm). The students were divided up into six groups of ten each in order to study two types of optimization First, Smallwood (1962), and Groen and Atkinson (1966) have provided models indicating that if the learning can be characterized as an incremental process to be specified by a linear operator model of the form, the probability of an incorrect response, $q_{i,n+1} = aq_{i,n}$, then a uniform distribution sequence rule for the curriculum elements will lead to optimal results. On the other hand, if the learning can be characterized as a Markoff process involving a learned and unlearned state, then the trial-to-trial independence of the Markoff process implies a drop-out sequencing strategy, that is, the instructional strategy drops out correct items because of their being absorbed into the learned state and repeats the instruction on the current error or unlearned words. Obviously a CAI system is ideally suited for keeping track of the student's spelling performance on each word and composing each practice list according to either the uniform or drop-out sequencing strategy.

Secondly, Suppes (1964) has proposed for language material that a double linear operator model (one operator characterizing the learning process and one operator characterizing the forgetting process) can imply one of two optimal approaches to forming the block size or list length of the words to be studied. Quite simply, if the learning is greater than the forgetting, the Suppes model implies that a whole list approach is more optimal. While if the converse is true for the learning and forgetting parameters, then a highly segmented block or part approach is optimal. Given the individual differences within learning and forgetting processes for eight year olds, it was hypothesized that students could be more optimally assigned an appropriate block size or length of their spelling list depending on both their learning and forgetting rates. Thus the assignment of the list size or block structure should be made dynamically from session to session.

Using thirty psuedo English words as the content for the spelling task, the six groups were assigned daily sessions according to the following instructional strategies: (1) Part--Drop-Out Strategy: the list size was five in length and within each inter-list interval, correct words were dropped and new words from the total list were inserted; (2) Part--Uniform Strategy: a list size of five words was practiced for six repetitions on each day with appropriate randomization; (3) Optimal Block Size--Drop-Out Strategy: list sizes of five, fifteen, or thirty were utilized according to the estimated learning rates of the student and correct items were removed during repetition; (4) Optimal Block Size--Uniform Strategy: list sizes of five, fifteen, and thirty were applied according to the estimated learning rates of the students while sequencing was uniformly distributed throughout the words; (5) Whole--Drop-Out Strategy: students studied the full list of thirty words once per session with correct words being removed on a session-to-session basis, and (6) Whole--

Uniform Strategy: students studied the total list once per session with appropriate randomization of the serial presentation. Thus, each student received six training sessions and a twenty-four hour retention test. The results are presented in Table 5.

TABLE 5.--Mean Proportion of Correct Spelling Responses for Six Instructional Strategies

	PART		OPTIMAL BLOCK		WHOLE	
SESSIONS	DROP-OUT STRATEGY	UNIFORM STRATEGY	DROP-OUT STRATEGY	UNIFORM STRATEGY	DROP-OUT STRATEGY	UNIFORM STRATEGY
1	.43	.63	.23	.31	.08	.09
2	.45	.66	.39	.46	.09	.13
3	.43	.71	.51	.58	.17	.28
4	.55	.75	.67	.63	.39	.47
5	.61	.85	.87	.77	.63	.57
6	.75	.89	.96	.84	.79	.61
Retention Test	.57	.43	.93	.73	.77	.55

A repeated measure analysis of variance indicated that the optimal block-drop-out strategy provided both the best learning as well as final retention performance outcome. As consistent with prior research (Dear et al., 1965), the drop-out strategy led to better retention results although the acquisition tended to interact with the block size, that is, better learning under the drop-out strategy occurred with larger block sizes. Thus, these results illustrate how the application of two learning models and their implied instructional strategy sequencing rules can lead to more optimal results. As additional confirmation of the approach, the students under the optimal block drop-out strategy had mean correct latencies of approximately 13 percent less than any of the other groups. Thus for classes of curriculum elements that tend to be learned in unitary or All-or-None fashion the use of CAI optimization techniques can have substantial payoff. The application of optimal instructional strategies via CAI can lead to maximizing on the desired criterion performance level as well as increased efficiency due to decreased learning time requirements.

Learning Strategies

Student learning strategies are important in that the psychological memory and concept formation processes reflect individual variation within encoding, consolidation, confidence, and affect reactions like anxiety. Offering a student control over rate or sequence can lead to increased performance given a high degree of prior competence. Thus consideration of student learning strategies within CAI can be approached as an interactive negotiation process: the better the performance by the student, the more self-selection and initiative should be offered concerning learning topics, alternative media, or amounts of practice.

One approach to applying learning strategies within CAI would be to consider the developmental stages and patterns of the students. The previously reviewed study by Gay (1969) on student control of the amount of practice on polynomial concepts indicated that the boys who were provided an opportunity for self-selection of examples performed better. In the United States, adolescent males are found to have more advanced autonomy indices and self-conceptions of higher confidence in comparison with females. Thus this heightened level of personality processes can influence their learning strategies and indicate how broader psychological variables should be considered within CAI sequencing strategies.

Perhaps more persuasively, a study by Proctor (1968) indicated that teacher candidates, when given the opportunity to explore the concepts representing current curriculum theory, perform approximately twenty percent better than a group who had a prescribed, logical route through the CAI materials. It is important to understand that the self-selection process has to be offered primarily to the better students. When offered to this group, it will lead to a stronger commitment by the brighter students to achieve the behavioral objectives typically found within CAI curriculum.

Turning to the issue of anonymity within instructional strategies, it appears based on the results from our laboratory that students find an anonymous role to be self-satisfying and allows for greater curiosity. Self-exploration without the typical negative social detriments found in a peer group can be facilitated via CAI. In a recent study (Lawler and Hansen, in preparation) investigating understanding of the concepts of the physiology of reproduction, birth control, and social morals concerning sex, the college students found the anonymous role to be both self-satisfying and self-adapting. By employing the technique of confidence ratings, we increase the reliability of the test outcome from .40 to .70 plus having superior performance levels. Moreover, self-report measures clearly indicate that the students felt that interacting with the CAI terminal was far less threatening and far less alienating in terms of its punishing remarks than a human interviewer, be he either a peer or an adult.

Continuing this topic of students' natural proclivity for anonymous interaction and individualized student control, a study by Smith (1968) performed a little over a year ago indicated that college students, when offered computer-based counseling, considered that the CAI system was vastly superior in terms of accuracy as well as conveying a heightened trust for the academic recommendations presented via the terminal. More surprisingly, the faculty counselors at the local junior college indicated that the computer system not only was more accurate, more knowledgeable, but made equivalent academic recommendations as they would offer, given that they had been thoroughly trained as to the multitude of alternatives found within their academic institutions. Thus, CAI may offer a very promising way to resolve some of the tensions and ambiguities commonly found when human beings in our society interact about high risk or critical valued problems as career selection and preparation.

As a final example of the application of student learning strategy, an investigation into the efficacy of CAI based learning games with the accompanying utilization of a CAI information retrieval system (Adair et al., 1969) indicate that such higher order behaviors as the ability to provide valid and powerful explanations based upon social science generalizations can be brought about via CAI. Using an information retrieval system having in excess of five thousand social science generalizations and accompanying background source documents, forty college students revealed growing ability to generate more sophisticated explanations based upon the information searched within and retrieved from the CAI based IR system. Accompanying attitudinal data indicates that the students find this form of man-machine interaction far more intellectually challenging and involving than that typically found in a college discussion section. The game aspect of the experiment which involved having students work on similar puzzling case studies also indicates multi-person approaches to the utilization of CAI interaction can have great learning payoff. This inquiry into the broader utilization of CAI and information retrieval, while still early in its development, offers a promising approach to small group interaction; a feature desired within many pedagogical situations.

Conclusions

This broad survey of the current research in CAI indicates both the growing efficacy of this form of man-machine interaction as well as the minimum range of investigations in terms of curriculum content and potential configurations of students and pedagogical routines. One would predict that the next decade forcasts a growing endeavor to develop more quantitative models representing both instructional strategies as well as student learning strategies. As we gain greater insight into the potential role of these quantitative approaches to instructional theory, one can anticipate greater benefits to our attempts to individualize instruction. With the growing commitment to expanding the educational enterprise in many countries, the use of computer technology offers great promise as one technique by which to retain the flavor of the master scholar interacting with his student.

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Computer-Assisted Instruction (CAI) is surveyed in terms of both the extent of research progress as well as the degree of utilization for this new technological approach to education. After a brief review of some of the critical terminology used to describe research progress within CAI, the paper develops a conceptual framework by which to consider current investigatory efforts. The first section deals with the psychological nature of the CAI situation. The second introduces concepts of how CAI provides for invidivudalization of instruction. Third, it introduces the procedures and research findings for the use of instructional strategies. The paper concludes with a discussion of learner strategies and their growing importance within CAI in learning investigations.

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Dr. James J. Regan
Naval Training Device Center
Orlando, Florida 32813

Chief, Aviation Psychology Division
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Behavioral Sciences Department
Naval Medical Research Institute
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Mr. Michael Macdonald-Ross
Instructional Systems Associates
West One
49 Welbeck Street
London WIM 7HE
ENGLAND

Commanding Officer
U. S. Naval Schools Command
Mare Island
Vallejo, California 94592

Dr. Don C. Coombs, Assistant Director
ERIC Clearinghouse
Stanford University Palo Alto, California 94305

Scientific Advisory Team (Code 71)
Staff, COMASWFORLANT
Norfolk, Virginia 23511

ERIC Clearinghouse
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Education & Training Developments Staff
Personnel Research & Development Lab.
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LCDR J. C. Meredith, USN (Ret.)
Institute of Library Research
University of California, Berkeley
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Mr. Joseph B. Blankenheim
NAVELEX 0474
Munitions Building, Rm. 3721
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Commander
Operational Test & Evaluation Force
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Arlington, Virginia 22209

Research Psychologist
SCBB, Headquarters
Air Force Systems Command
Andrews Air Force Base
Washington, D. C. 20331

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Chief, Analysis Division (AFPDPL)
Washington, D. C. 20330

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Washington, D. C. 20330

Dr. Alvin E. Goins, Executive Secy.
Personality & Cognition Research
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Behavioral sciences Research Branch
National Institute of Mental Health
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Chevy Chase, Maryland 20203

Dr. Mats Bjorkman
University of Umea
Department of Psychology
Umea 6, Sweden

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Washington, D. C. 20036
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Mr. Joseph J. Cowan
Chief, Personnel Research Branch
U. S. Coast Guard Headquarters
PO-1, Station 3-12
1300 "E" Street, N. W.
Washington, D. C. 20226

Executive Officer
American Psychological Association
1200 Seventeenth Street, N. W.
Washington, D. C. 20036

Mr. Edmund C. Berkeley
Information International, Inc.
545 Technology Square
Cambridge, Massachusetts 02139

Dr. Donald L. Bitzer
Computer-Based Education Research
Laboratory University of Illinois
Urbana, Illinois 61801

Dr. C. Victor Bunderson
Computer-Assisted Instruction Lab.
University of Texas
Austin, Texas 78712

Dr. F. J. DiVesta
Education & Psychology Center
Pennsylvania State University
University Park, Pennsylvania 16802

Dr. Philip H. DuBois
Department of Psychology
Washington University
Lindell & Skinker Boulevards
St. Louis, Missouri 63130

Dr. Wallace Feurzeig
Bolt, Beranek & Newman, Inc.
50 Moulton Street
Cambridge, Massachusetts 02138

Dr. Robert Glaser
Learning Research & Development Center
University of Pittsburgh
Pittsburgh, Pennsylvania 15213

Dr. J. P. Guilford
University of Southern California
3551 University Avenue
Los Angeles, California 90007

Dr. Albert E. Hickey
Entelek, Incorporated
42 Pleasant Street
Newburyport, Massachusetts 01950

Dr. Howard H. Kendler
Department of Psychology
University of California
Santa Barbara, California 93106

Dr. Robert R. Mackie
Human Factors Research, Inc.
6780 Cortona Drive
Santa Barbara Research Park
Goleta, California 93107

Dr. Gabriel D. Ofiesh
Center for Educational Technology
Catholic University
4001 Harewood Road, N. E.
Washington, D. C. 20017

Dr. Joseph W. Rigney
Electronics Personnel Research Group
University of Southern California
University Park
Los Angeles, California 90007

Dr. Arthur I. Siegel
Applied Psychological Services
Science Center
404 East Lancaster Avenue
Wayne, Pennsylvania 19087

Dr. Lawrence M. Stolurow
Harvard Computing Center
6 Appian Way
Cambridge, Massachusetts 02138

Dr. Benton J. Underwood
Department of Psychology
Northwestern University
Evanston, Illinois 60201

Dr. Joseph A. Van Campen
Institute for Math Studies in the Social Sciences
Stanford University
Stanford, California 94305

Dr. John Annett
Department of Psychology
Hull University
Yorkshire
ENGLAND

Dr. M. C. Shelesnyak
Interdisciplinary Communications Program
Smithsonian Institution
1025 Fifteenth Street, N. W.
Suite 700
Washington, D. C. 20005

Dr. Lee J Cronbach
School of Education
Stanford University
Stanford, California 94305

Dr. John C. Flanagan
Applied Institutes for Research
P. O. Box 1113
Palo Alto, California 94302

Dr. M. D. Havron
Human Sciences Research, Inc.
Westgate Industrial Park
7710 Old Springhouse Road
McLean, Virginia 22101

Dr. Roger A. Kaufman
Department of Education
Institute of Instructional System Technology & Research
Chapman College
Orange, California 92666

Dr. Carl E. Helm
Department of Educational Psychology
Graduate Center
City University of New York
33 West 42nd Street
New York, New York 10036

S. Fisher, Research Associate
Computer Facility
Graduate Center
City University of New York
33 West 42nd Street
New York, New York 10036

Dr. Marshall J. Farr
Assistant Director, Engineering
Psychology Program
Office of Naval Research (Code 455)
Washington, D. C. 20360

LTC Philip H. Enslow, Jr.
46 Putnam Circle
Woodbridge, Virginia 22191

(F)

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Research Officer
The University of Leeds
Leeds, ENGLAND

Dr. William F. Atchison
Director, Computer Science Center
University of Maryland
College Park, Maryland 20742

Dennis O. Barnes
Instructional Technology Department
University of Southern California
801 Phillips Hall
Los Angeles, California 90007

Dr. Ernest Burkman, Jr.
Associate Professor
Science Education
FSU, Kellum Hall Basement
Tallahassee, Florida 32306

Dr. Thomas C. Capraro
33 Dining Hall
Florida State University
Tallahassee, Florida 32306

Dr. Sylvia Charp
School District of Philadelphia
21st and the Parkway
Philadelphia, Pennsylvania 19103

Mr. John E. Coulson
Education Systems Department
Public Systems Division
System Development Corporation
2500 Colorado Avenue
Santa Monica, California 90406

John F. Feldhusen
Educational Psychology Section
Purdue University
Lafayette, Indiana 47907

William F. Fitzerald
The Department of Education
University of Chicago
5835 S. Kimbark Avenue
Chicago, Illinois 60637

Dr. John C. Flanagan
American Institutes for Research
P. O. Box 1113
Palo Alto, California 94302

Dr. E. N. Adams, Director
Computer-Assisted Instruction
IBM Instructional Systems
Development Department
Watson Research Center
Box 218
Yorktown Heights, New York 10598

Dr. Richard Atkinson
Institute of Mathematics
Ventura Hall
Stanford University
Stanford, California 94305

Dr. Victor Bunderson
Director of Computer-Assisted
Instruction Laboratory
The University of Texas
College of Education
Austin, Texas 78712

Donald D. Bushnell
Associate Director
Brooks Foundation
2020 Alameda Padre Serra
Santa Barbara, California 93103

Dr. Vincent Cieri
CAI Project
Bldg. 641
U. S. Army Signal Center & School
Ft. Monmouth, New Jersey 07703

Dave Dasenbrock
CREI--McGraw Hill
3225 Sixteenth Street, N. W.
Washington, D. C. 20010

Dr. James Duva
Code 554
Naval Training Device Center
Orlando, Florida 32813

Dr. Victor Fields
Personnel & Training
Office of Naval Research
Code 458
Main Navy Building
Washington, D. C. 20360

Dr. John Ford
U. S. Naval Personnel Research
Activity
San Diego, California

Mr. Ted Gettinger
Xerox Data Systems
Main Station 8301
S. Aviation Blvd.
El Segundo, California

Dr. David A Gilman
Department of Education and
Psychology
Indiana State University
Terre Haute, Indiana 47809

Dr. Joseph H. Grosslight
Department of Psychology
Florida State University
Tallahassee, Florida 32306

Keith A. Hall
201-202 Chambers Building
The Pennsylvania State University
University Park, Pennsylvania 16802

Carl Helm
Graduate Center
City University of New York
33 W. 42nd Street
New York, New York 10036

Dr. John Hemphill
The Far West Lab. for Education
Research & Development
Claremont Hotel
1 Garden Court
Berkeley, California 94705

Mr. Charles W. Jackson
5009 Holmes Avenue, N. W.
Huntsville, Alabama 35805

Dr. Robert M. Johnson
Director of Research
306 Dodd Hall
Florida State University
Tallahassee, Florida 32306

Dr. Edward Lambe
State University of New York
at Stony Brook
Stony Brook, Long Island,
New York 11790

Dr. Douglas Mayo
Naval Base Branch
Memphis Air Station
Memphis, Tennessee 38115

(H)

James E. Gilbert
Office of Educational Resources
Northeastern University
Boston, Massachusetts 02115

Dr. Jack Gillikin
U. S. Naval Academy
1000 Bayberry Road
Arnold, Maryland 21012

Dr. Robert Glaser
Learning Research and Development
Center
University of Pittsburgh
Pittsburgh, Pennsylvania 15213

Mr. Ralph Grubb
IBM Corporation
Monterey and Cottle Roads
San Jose, California 95111

Dr. John W. Hamblen
Southern Regional Education Board
130 Sixth Street, N. W.
Atlanta, Georgia 30313

Dr. Albert E. Hickey
42 Pleasant Street
Newburyport, Massachusetts 01950

Mr. Steven Hunka
Educational Research
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Edmonton, Alberta
CANADA

Dr. Russell P. Kropp
DIRS
Kellum Basement
Florida State University
Tallahassee, Florida 32306

Dr. Joseph Lipson
Nova University
Fort Lauderdale, Florida 33301

Dr. Elizabeth Lyman
Computer-based Education Research
Laboratory
University of Illinois
Urbana, Illinois 61803

Dr. Ingeborg Assman
683 Schwetzingen
Stressemann Street 3
GERMANY

Mr. Ed Massengill
Stafford-Massengill Corporation
Lexington, Massachusetts 02173

Dr. Robert M. Morgan
413 Education
Florida State University
Tallahassee, Florida 32306

Mr. James Prevel
Acting Chief, Equipment Development Branch
Bureau of Research, USOE
400 Maryland Avenue, S. W.
Washington, D. C. 20202

Dr. Wade Robinson, Chairman
CEMREL
10646 St. Charles Rock Road
St. Louis, Missouri

Dr. Robert Seidel
Hum RRO
Alexandria, Virginia

Dr. Lawrence M. Stolurow
Harvard Computing Center
33 Oxford Street
Cambridge, Massachusetts 01451

Dr. Leonard Uhr
Computer Sciences Department
The University of Wisconsin
1210 West Dayton Street
Madison, Wisconsin 53706

Dr. Hal Wilson
Director of Instructional Techniques and Systems
Harcourt-Brace
737 Third Avenue
New York, New York

Dr. Halim Ozkaptan, Chief
Human Factors
Martin Company
Orlando, Florida

Dr. Leo J. Postman
Institute of Human Learning
University of California
2241 College Avenue
Berkeley, California 94720

Dr. J. William Moore
Chairman, Department of Education
Bucknell University
Lewisburg, Pennsylvania

John Pagen
Director, INDICOM Project
Waterford Township School District
3576 CASs-Elizabeth Road
Pontiac, Michigan 48054

Dr. David Redfield
507 S. Woodward Street
ISCS
Florida State University
Tallahassee, Florida 32306

Dr. John J. Schurdak
Fairfield University
N. Benson Road
Fairfield, Connecticut

Dr. Harry F. Silberman
System Development Corporation
2500 Colorado
Santa Monica, California

Dr. Patrick Suppes
Institute of Mathematics
Stanford University
Stanford, California 94305

Max Weiner
Division of Teacher Education
City University of New York
33 W. 42nd Street
New York, New York 10036

Dr. Karl L. Zinn
Center for Research on Learning and Teaching
University of Michigan
Ann Arbor, Michigan 48108

Dr. James J. Asher
Department of Psychology
San Jose State College
San Jose, California 95114

Professor Magnus Stiernborg
Pedagogiska Institutionen
Gastrikegaten 10
Bos 6033
Stockholm 6
SWEDEN